Clouds in the ECMWF GCM

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Outline

Why are we doing this simulation

How is it being done

What we learned

Some conclusions

Take-home Message

The state of the atmosphere including clouds specified by ECMWF shows difficulties with convection

Inspite of the shortcomings the conversion of this state into infrared radiances shows amazing similarities to what AIRS observes.

These ECMWF simulated AIRS (and IASI) radiances will be a major asset for the evaluation of retrieval accuracy and skill.

Why are we doing this ECMWF simulation?

1) How realistic are the clouds in the ECMWF GCM?

2) Can the simulated data be used for the testing of L2 accuracy and skill.

Getting the clouds right in a GCM is critical.

If the clouds are wrong, then the albedo will be wrong. As result the amount of solar energy energy available to drive convection will be wrong.

If the GCM is free-running, then it will quickly diverge. Climate models are free-running GCMs.

GCMs for weather forecasting will not diverge because they are forced every 6 hours to agree with new truth data.

Since the basic parametrization GCMs for weather and for climate is the same, we can learn a lot from the evaluation of clouds in the ECMWF GCM.

Calculation of cloudy radiance

Cloudy radiances are calculated using the AIRS RTA (Feb 2009) developed at UMBC.

The RTA uses the PCLSAM scattering code, which reparameterizes scattering effects into an effective optical depth.

In the thermal IR, this code compares very well against established scattering codes such as DISORT or RTSPEC, with errors of about 2K for a cloud effect of about 40 K, but is orders of magnitude faster.

The calculation uses a two cloud model.

The two clouds are derived from the full ECMWF 91 level set of cloud amounts. One is an ice cloud, the other a water cloud. The algorithm look for the "limits" of the cloud profile and weights the cloud amount as a function of height.

For single layer clouds (like low stratus) or when the ice clouds are high (strong convection) this approach is accurate.

We used the ECMWF T(p), q(p) and cloud specification to calculated what AIRS should have seen and compared with what AIRS did see.

The calculations used the 1/4 degree ECMWF GCM available every three hours.

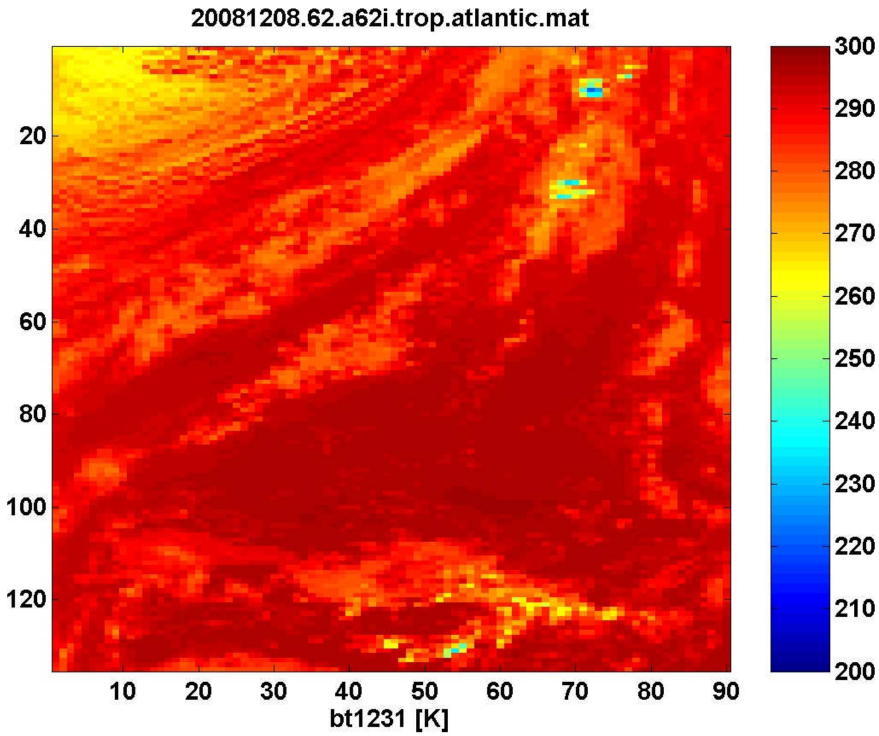
UMBC converted all ECMWF data from 20081208 into files which emulate the AIRS L1b files (90x135 spectra in 240 granules).

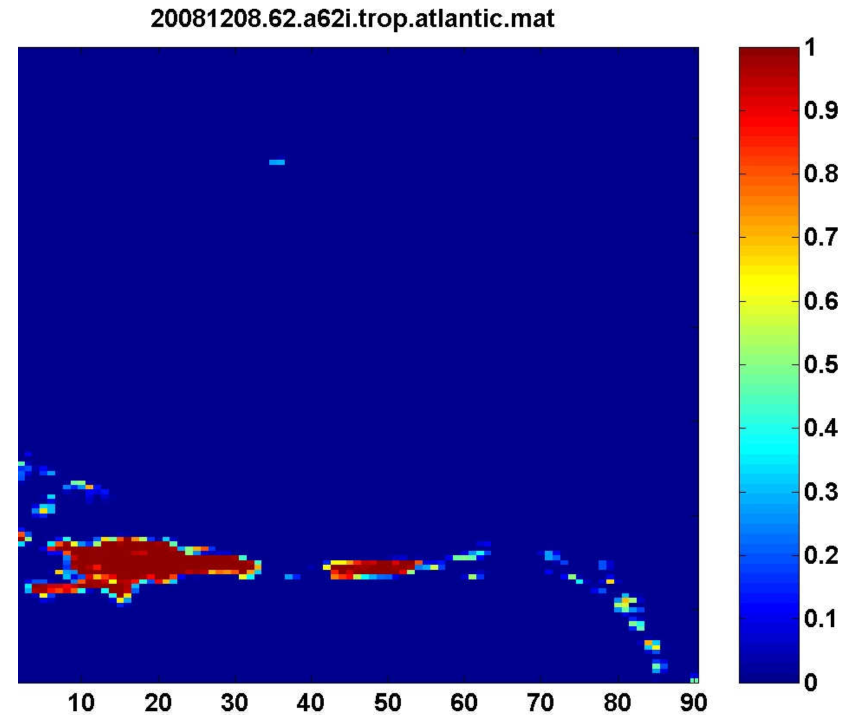
This data can be used as input to the L2 retrieval (Manning talk) to assess retrieval accuracy and skill, or we can analyzed the data in L1b domain directly.

We show results for two granules first, then we show results for global statistics for the whole day.

The 1st granule was located in the Atlantic ocean E. of Florida

Observed

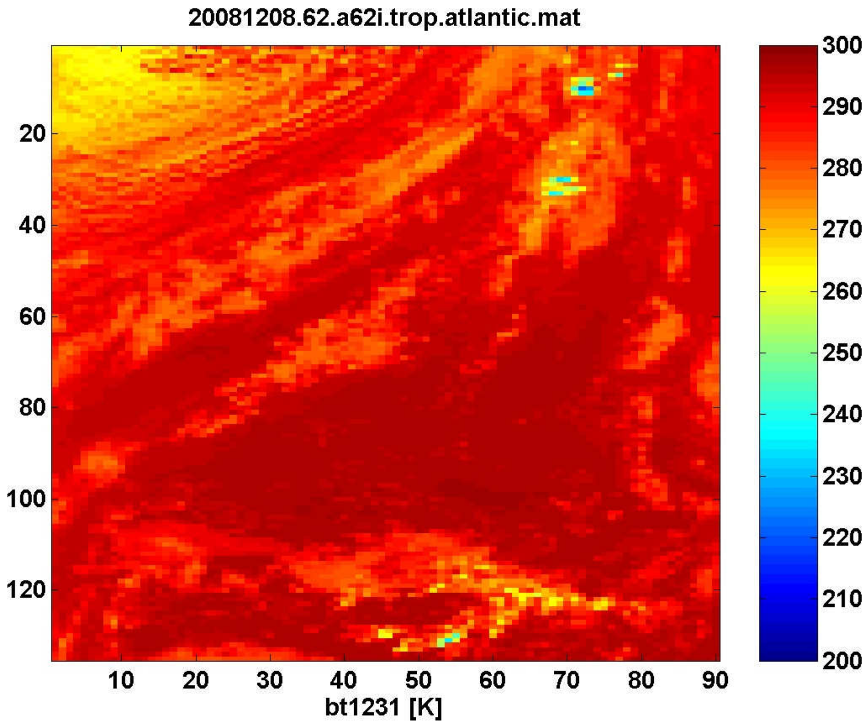


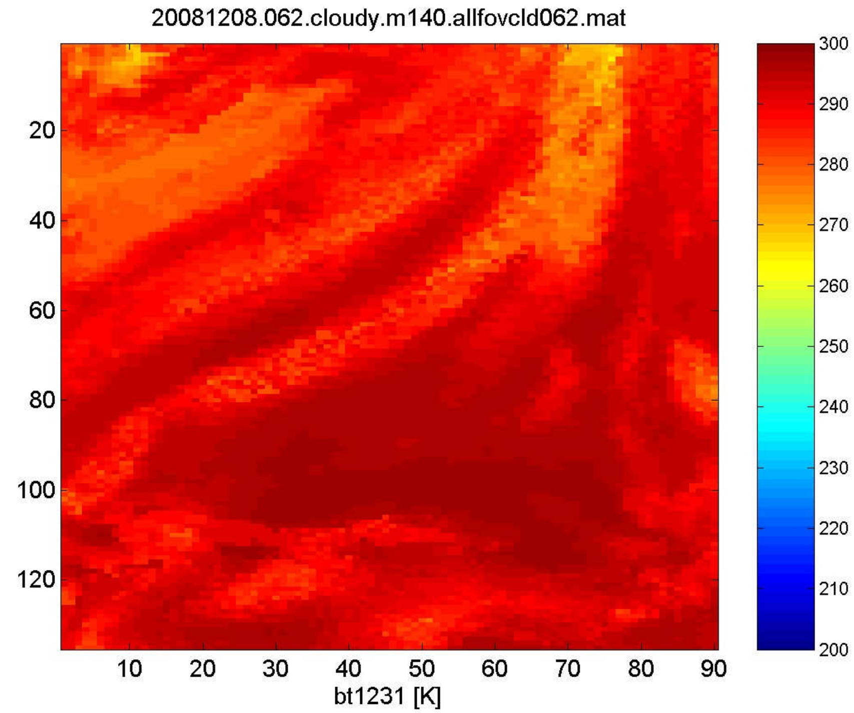


This granule included a mix of clear (dark red), mid level clouds (20-40 K colder than the surface, orange) and very few high clouds (clouds more than 50K, green and blue).

Good mid cloud patterns, but most high clouds are missing

Observed **Simulated**





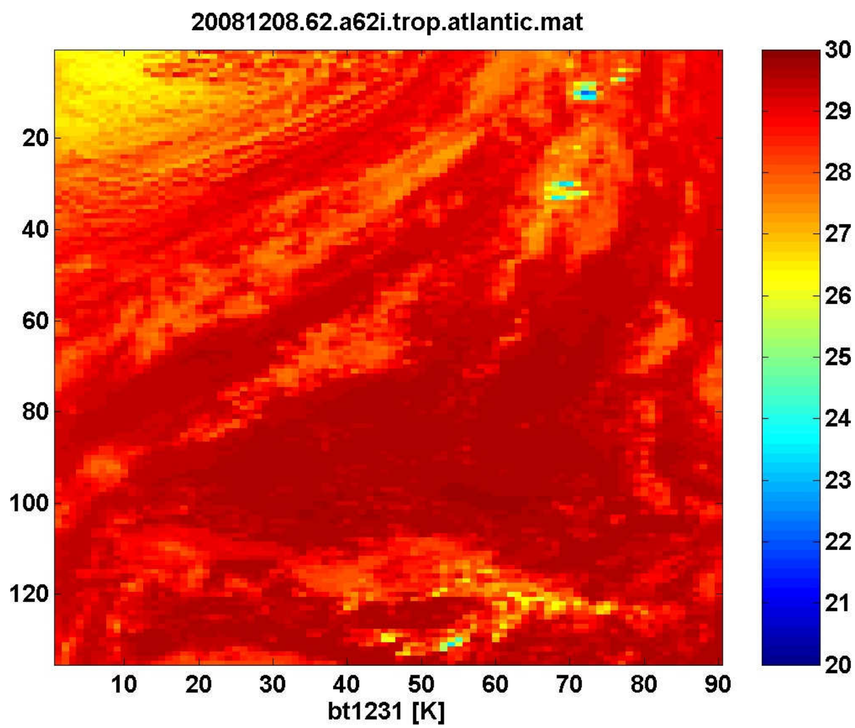
2415 clear of 11666 ocean spectra = 21%

3438 clear of 11666 ocean spectra = 29%

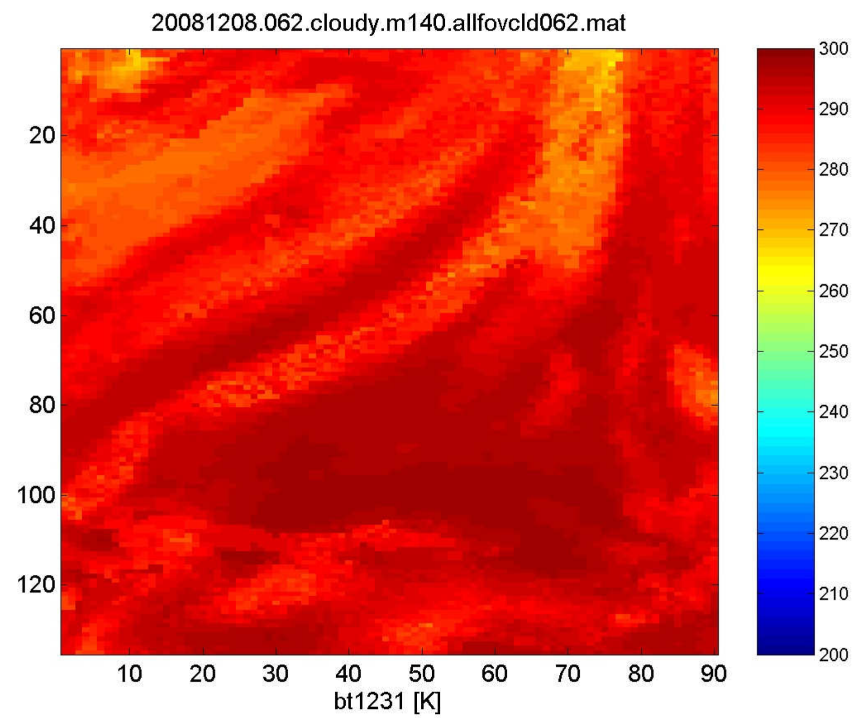
Clear means abs(obs-calc.1231)<1

The higher clear fraction is not due to FOV effects

Observed



Simulated



2415 clear of 11666 ocean spectra

3438 clear of 11666 ocean spectra

If the AIRS data were blurred from 18 km to 28 km, there would be fewer clear spots not more.

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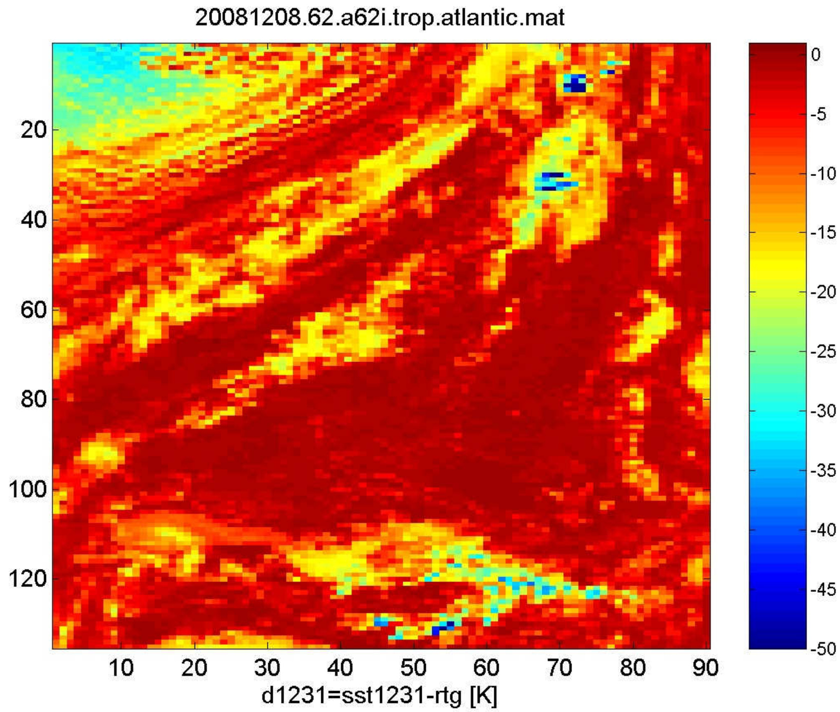
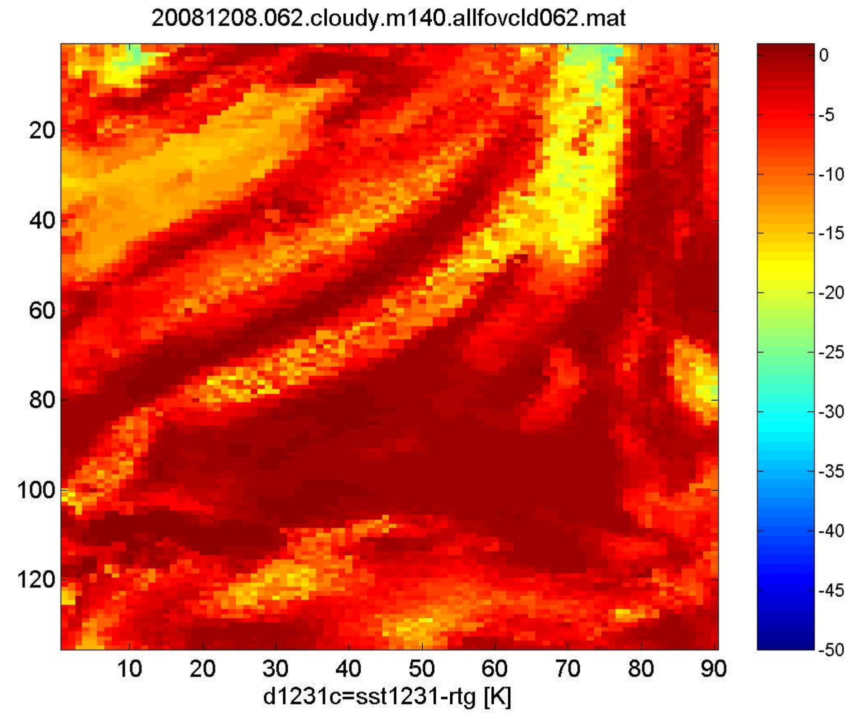
The simulated mid clouds are a little weaker than observed.

Observed



Simulated

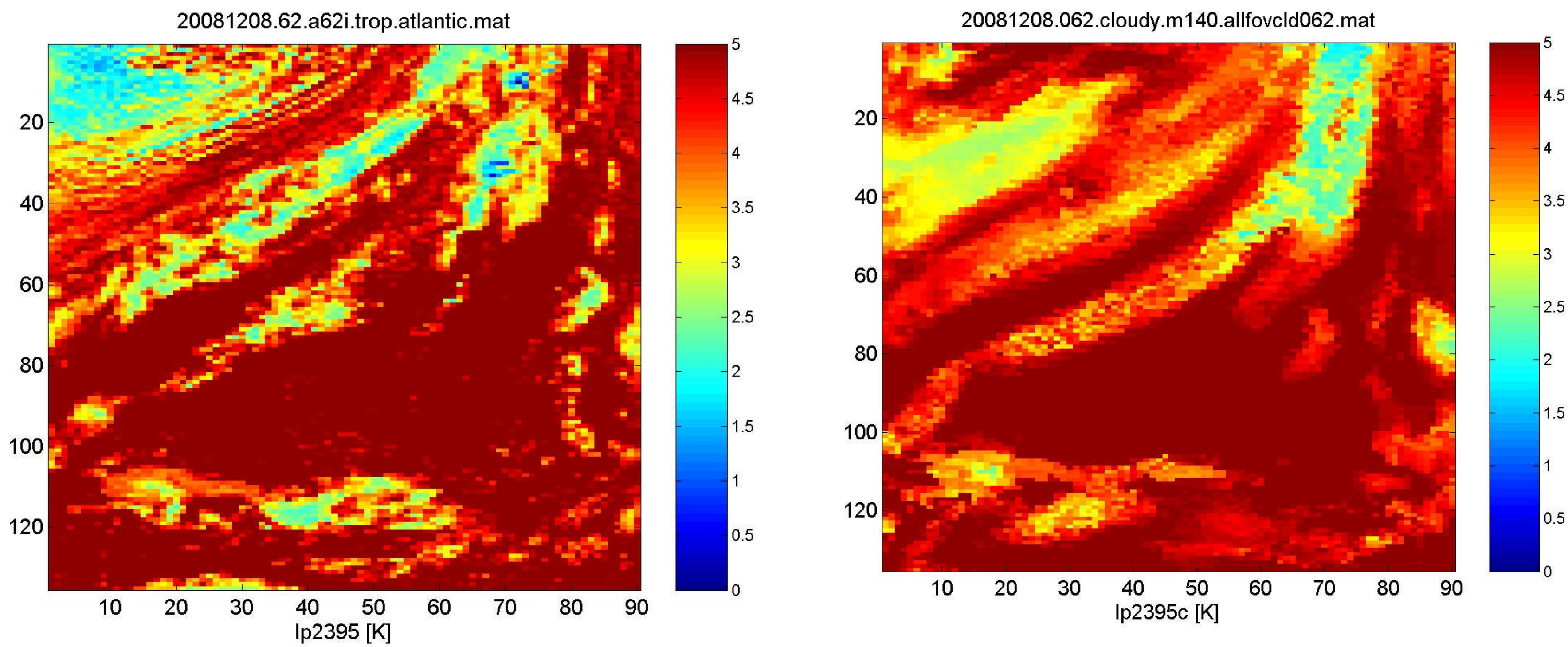


d1231=sst1231-stemp is a very useful metric.
abs(d1231)<1 means the FOV is almost cloud free

24 months mean day/night single FOV AIRS and IASI forecast clear = 23%

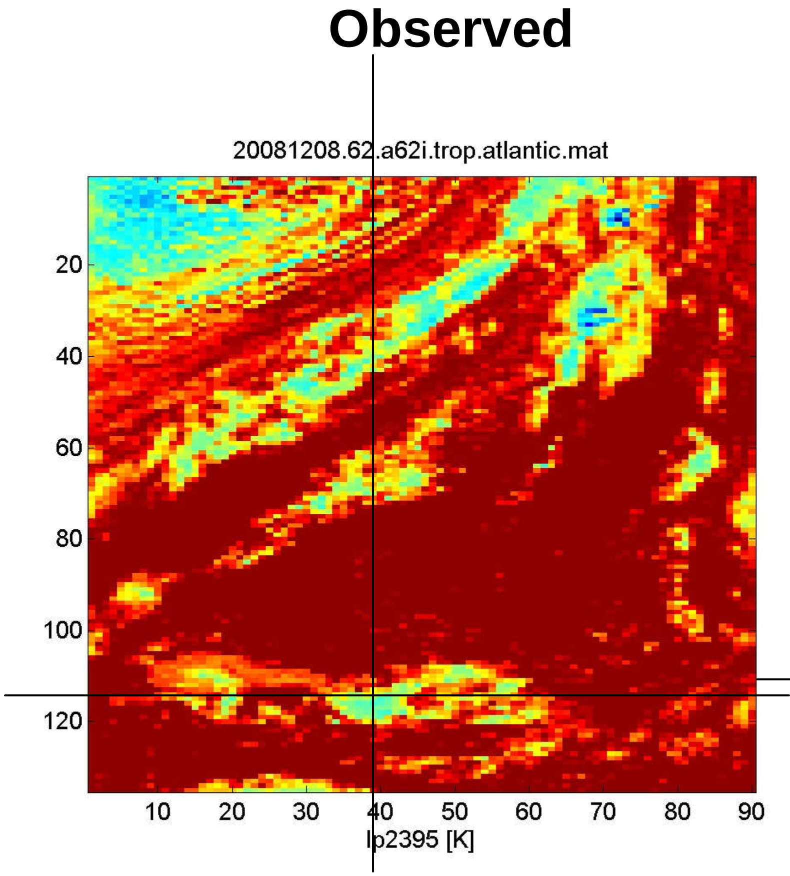
The pseudo lapse rates in ECMWF look realistic

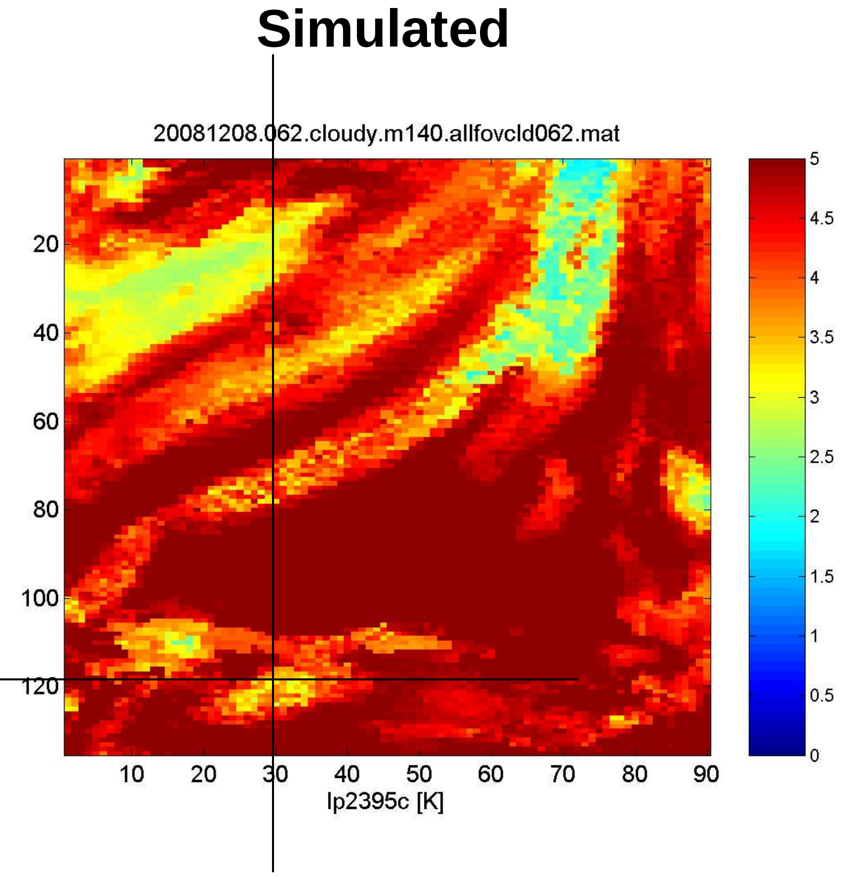
Observed **Simulated**



Pseudo lapse rate = bt2395-bt2392 700mb-400mb gradient

Some ECMWF clouds are found 100-200 km East of where AIRS found them.

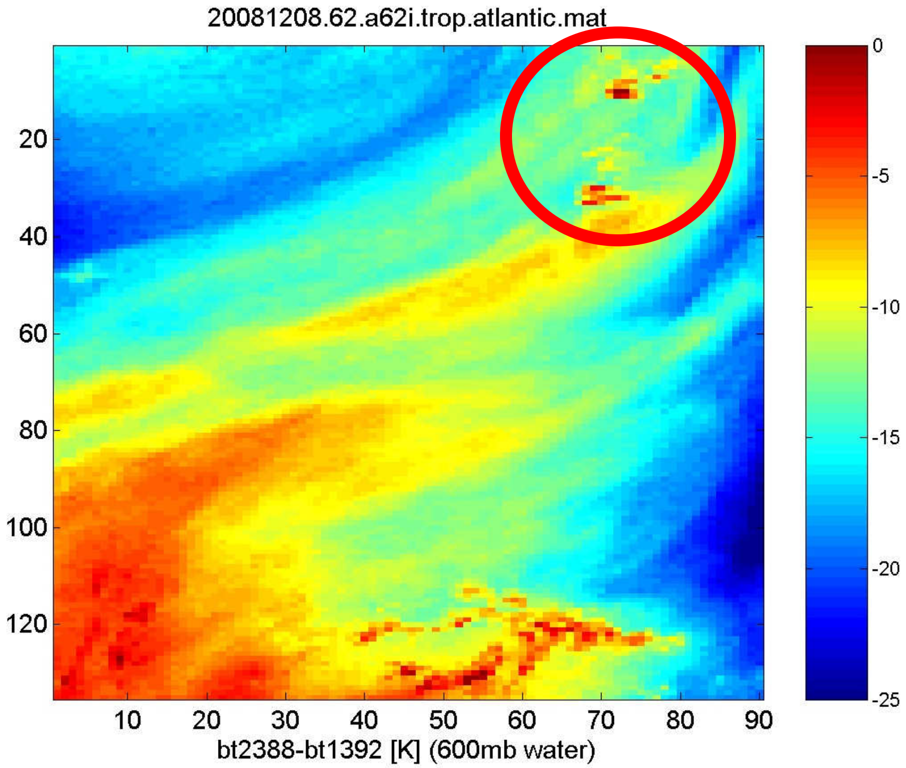




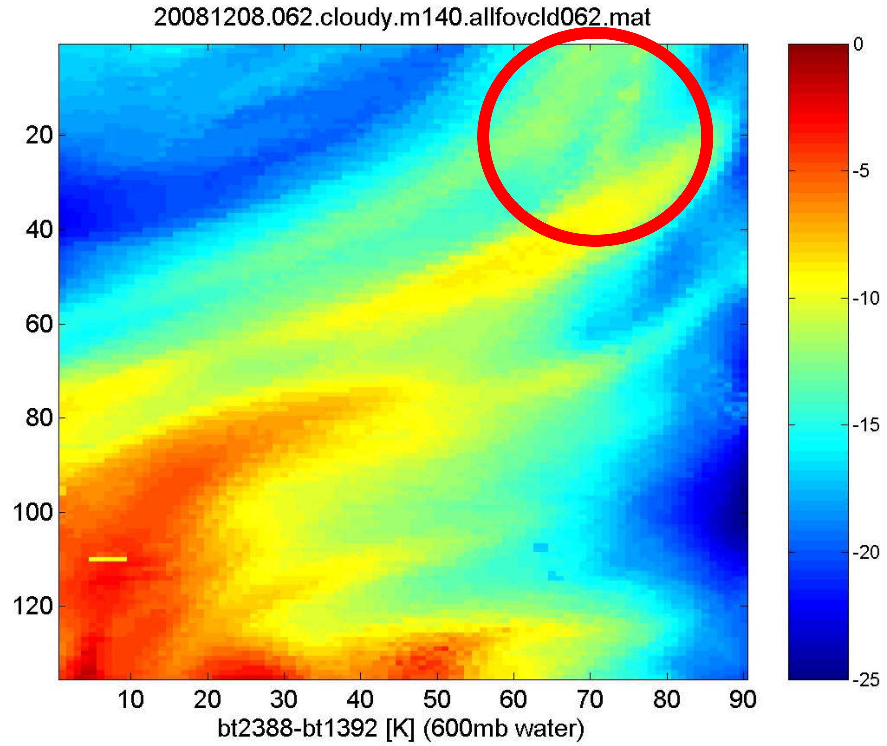
Each AIRS pixel is 0.16 degree in lat/lon near the equator. The observed displacement of 1.6 degree = 180 km is due to time interpolation error in the presence of high winds.

The 600 mb water vapor structure looks very nice, but is missing the strongest convection.

Observed

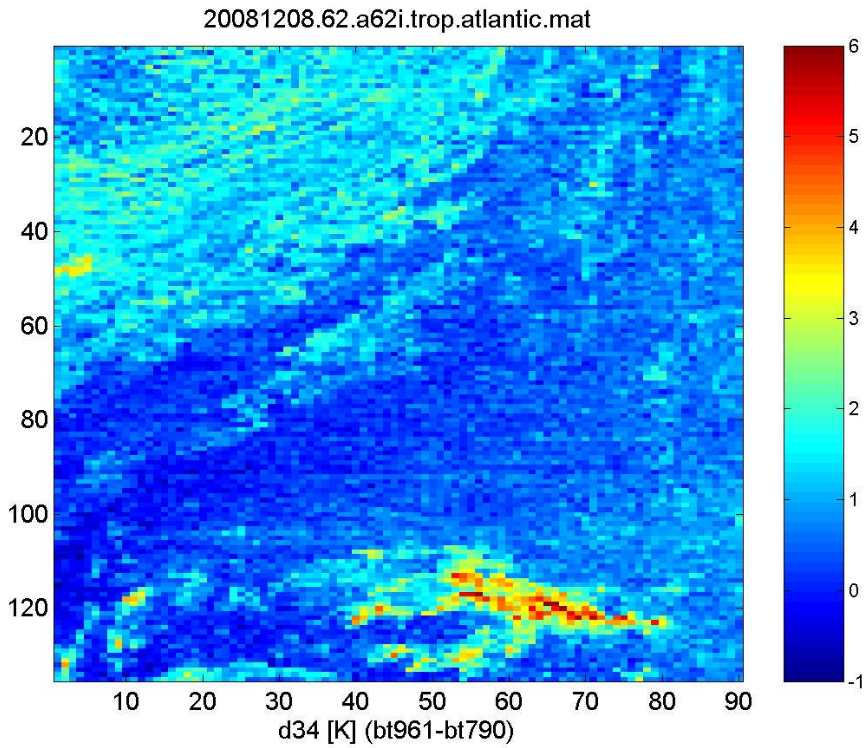


Simulated

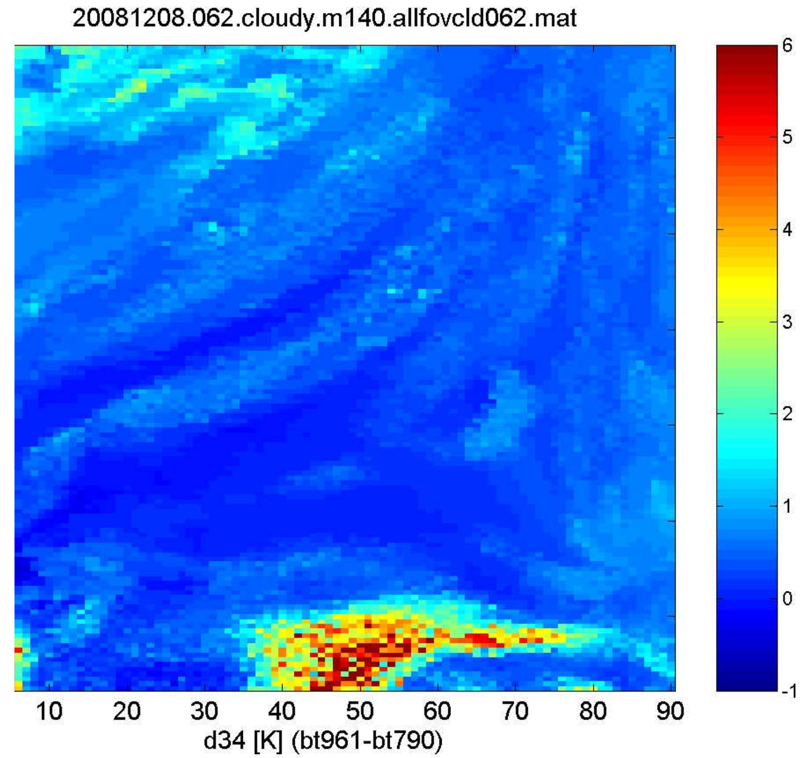


The cloud particle size in the simulation is too small

Observed



Simulated



D34 is the gradient between 961 and 790 cm-1, adjusted for water absorption. D34 is sensitive to the particle size in the clouds.

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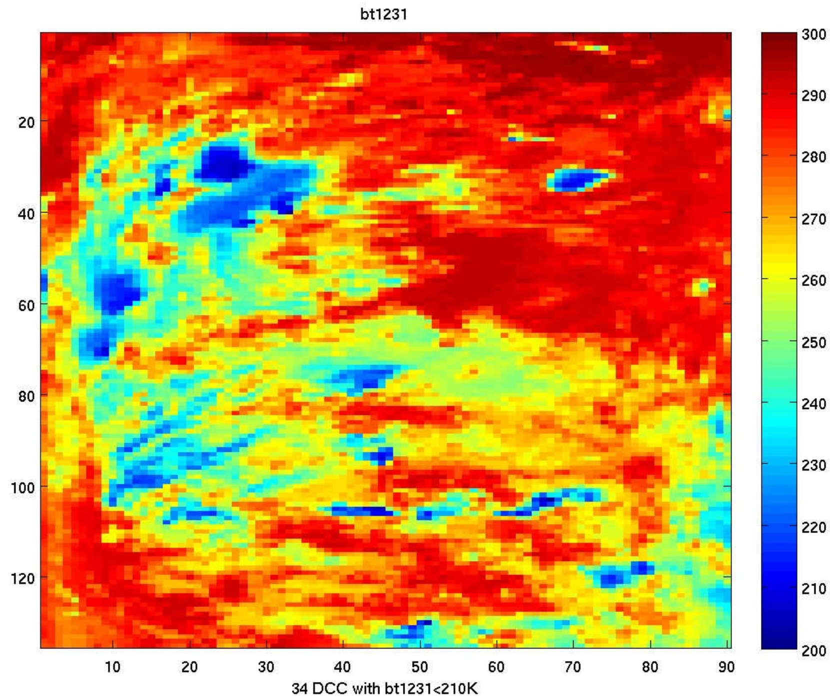
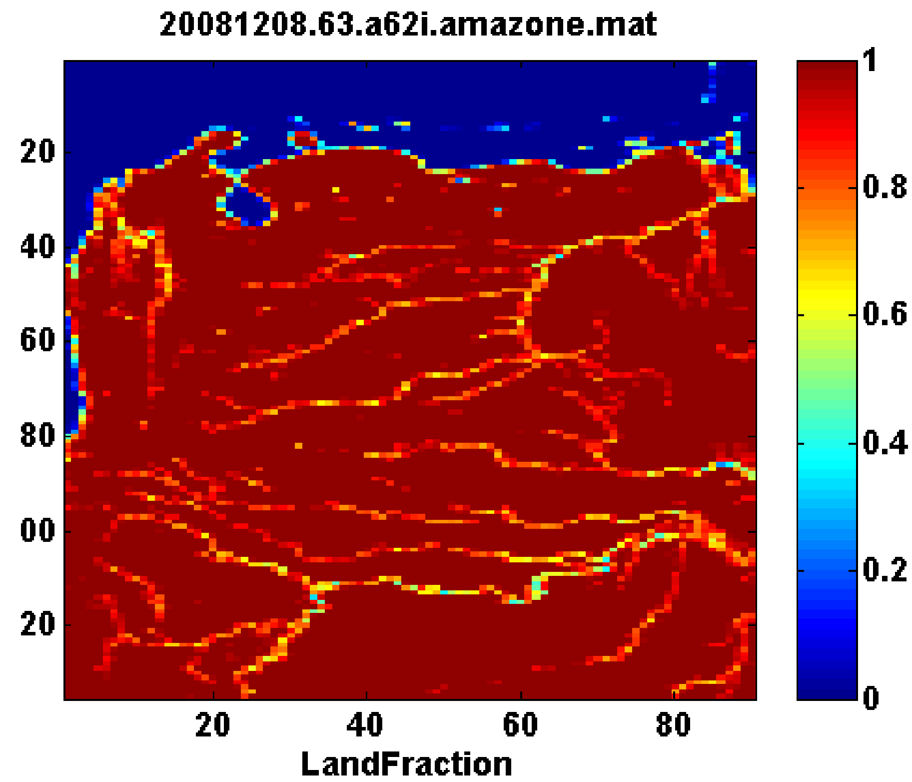
Evaluation of a granule 20081208.63

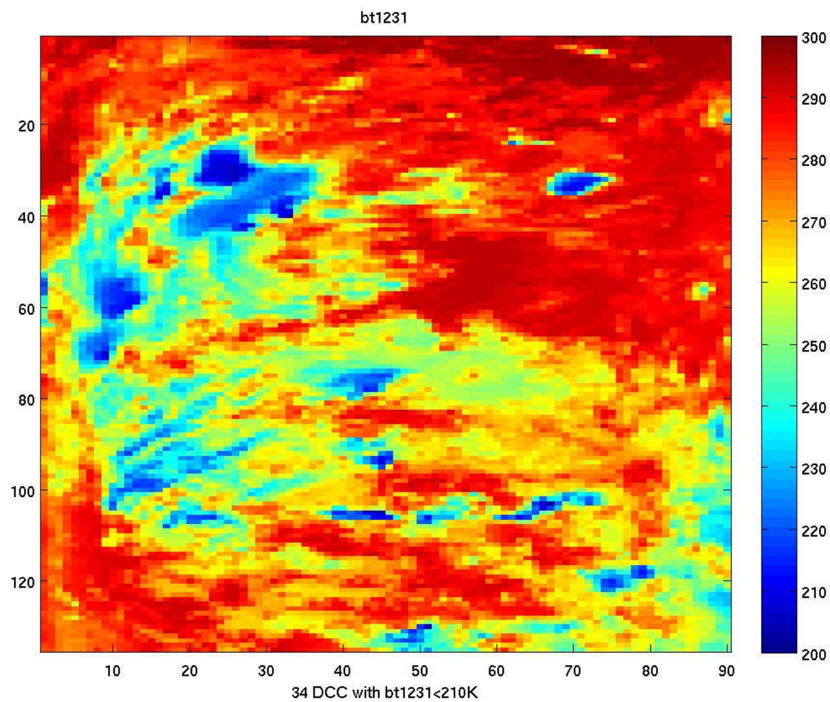
Observed



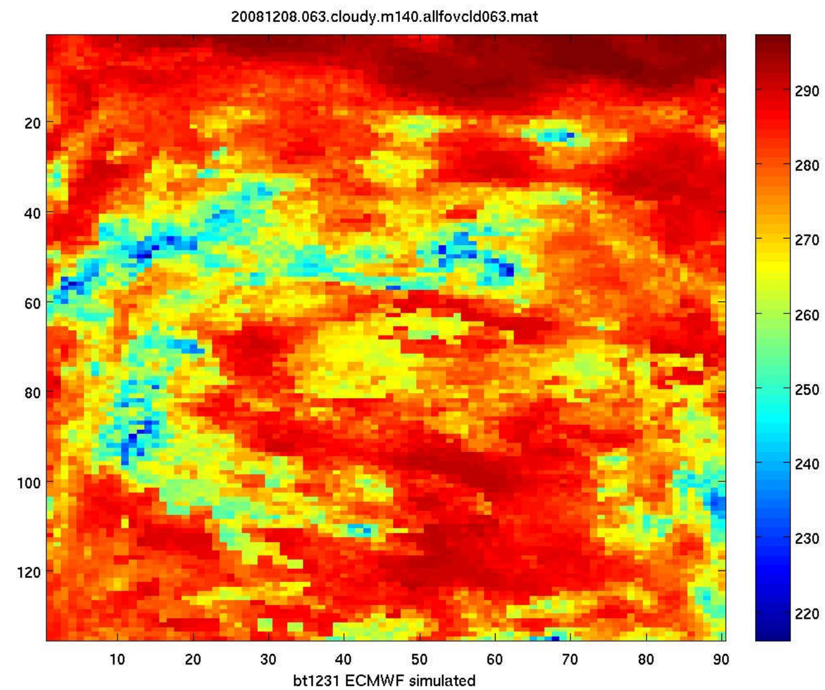


Evaluation of a granule 20081208.63

AIRS observed



simulated using ECMWF



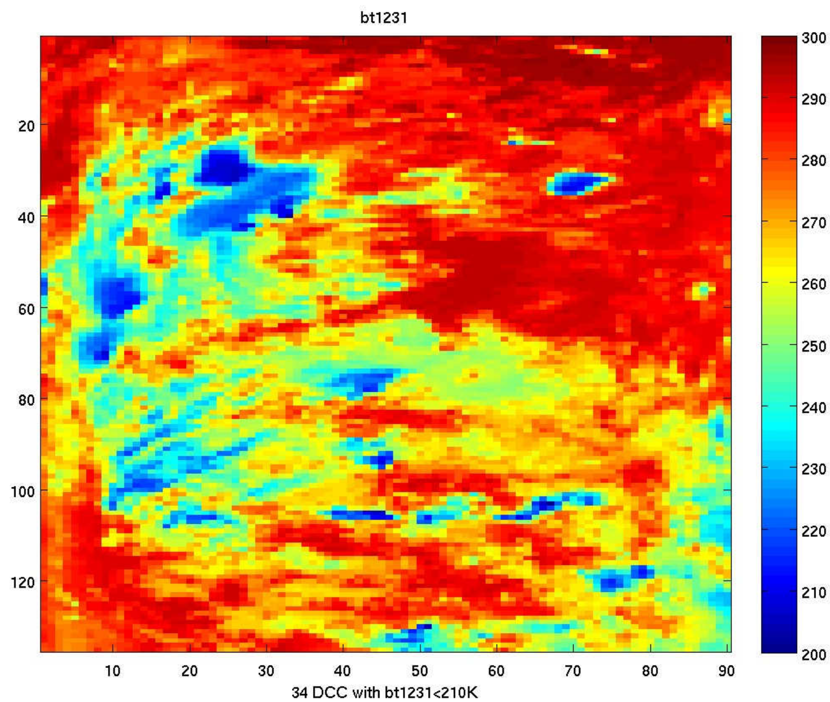
350 of 12150 Observed

d1231<1K forecast clear

363 of 12500 simulated

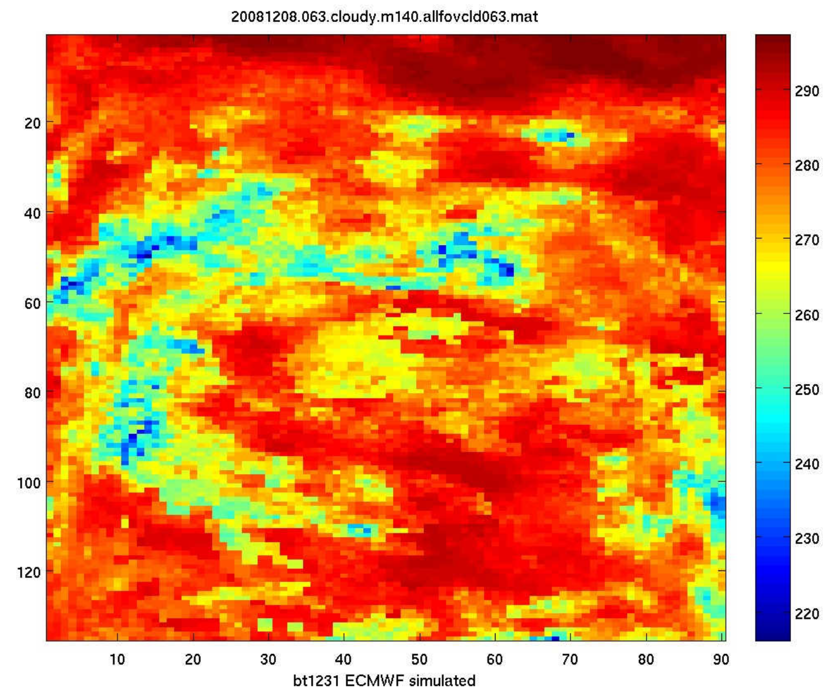
Evaluation of a granule 20081208.63 in the Amazon

AIRS observed



Observed 34 DCC

simulated using ECMWF



simulated 0 DCC

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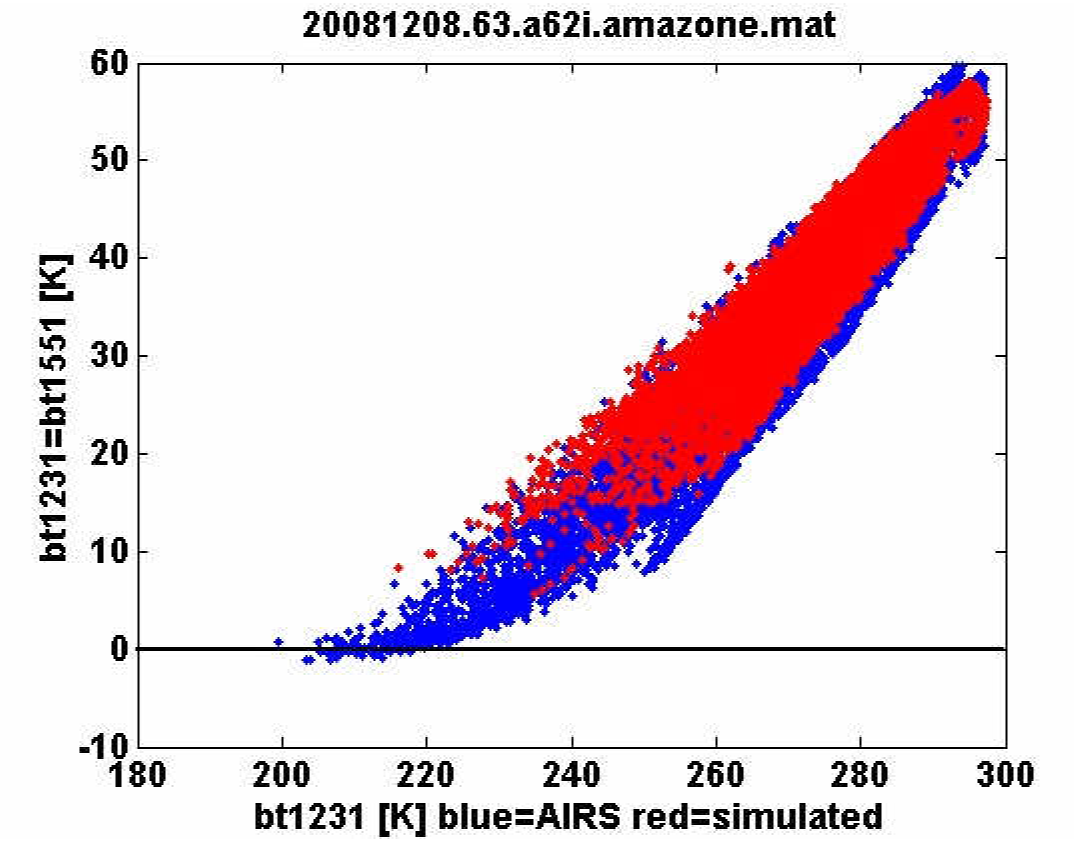
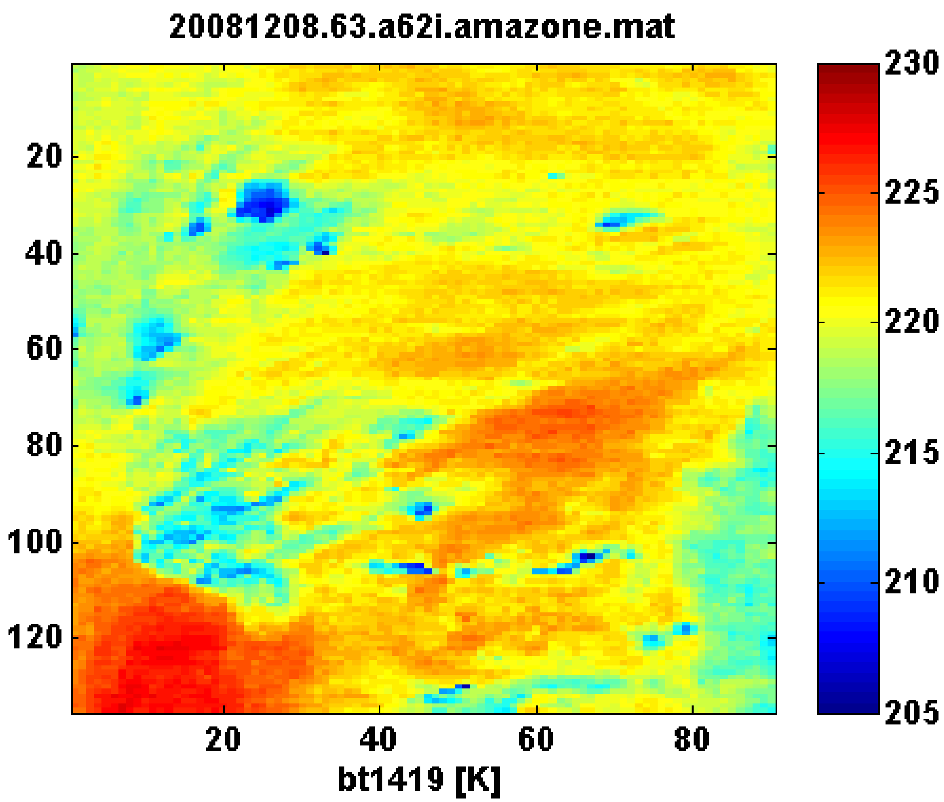
AIRS cloud tops reach through the tropopause cold point
No cloud tops colder than 220 K in the simulated data.

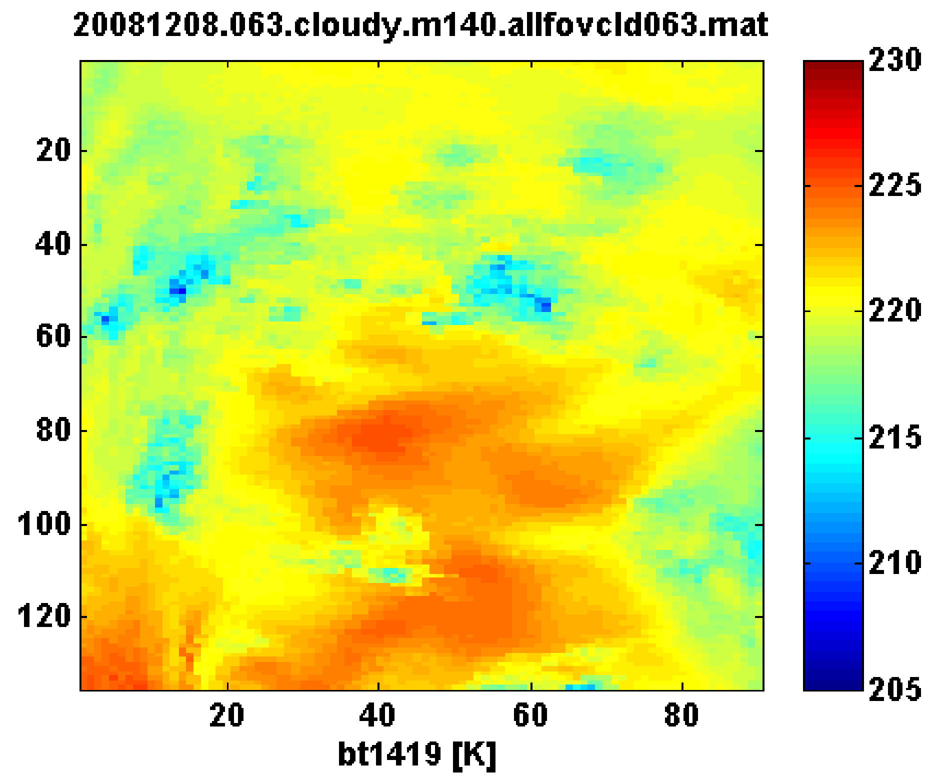


The 1419 water channel peaks near the tropopause

AIRS observed



simulated using ECMWF



AIRS is systematically colder = more water vapor
bt1419-bt1419.sim mean=-5 K stdev=15K

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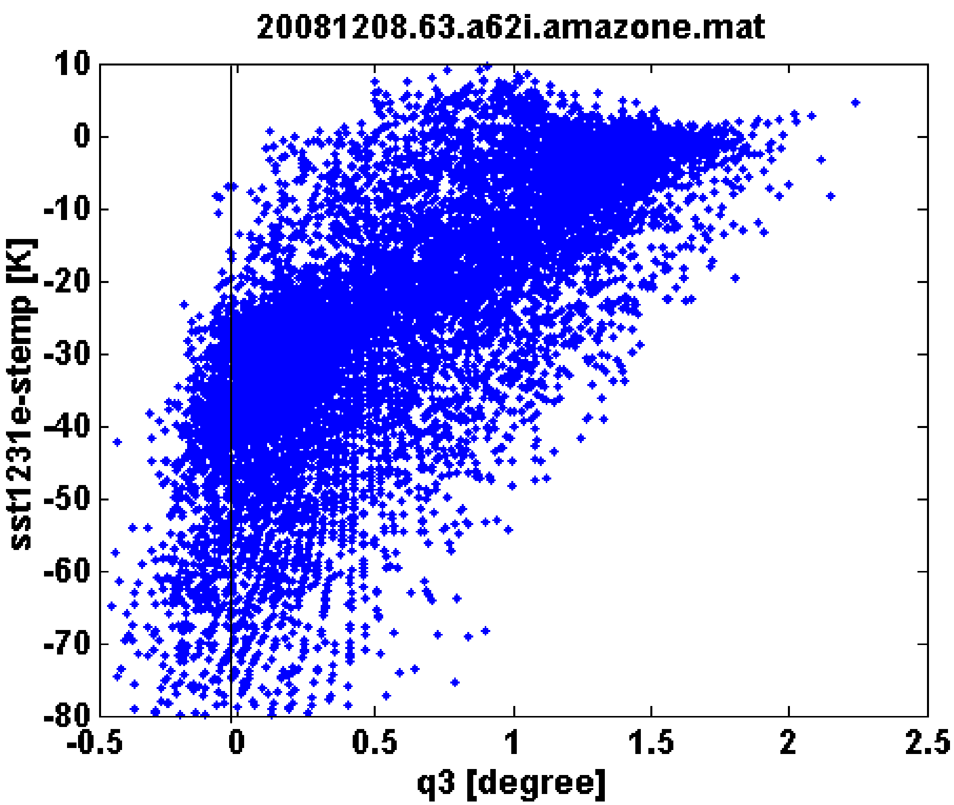
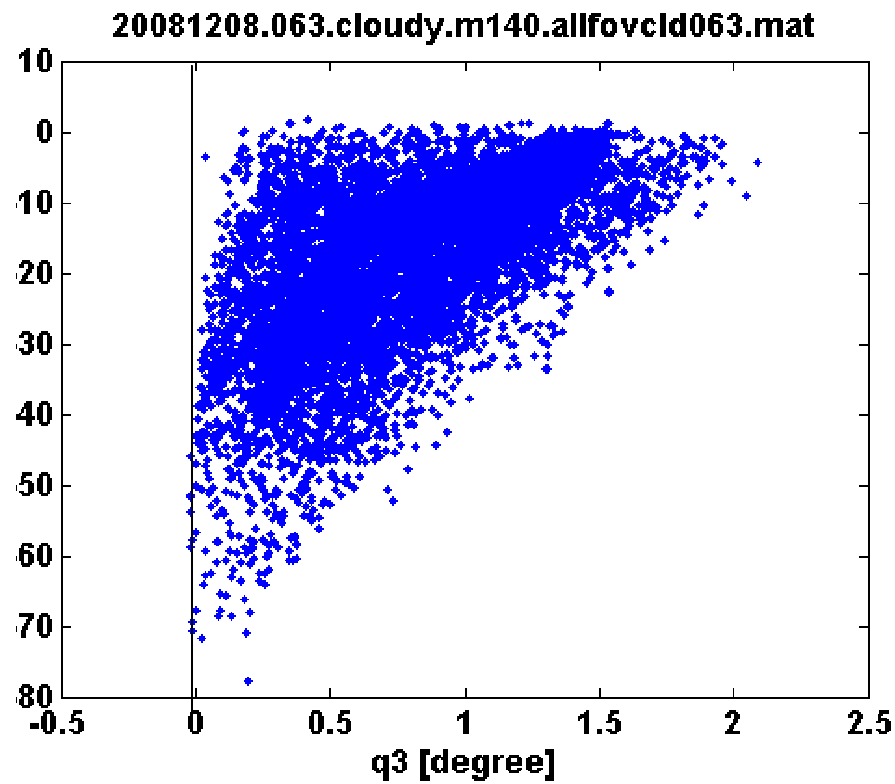
Lack of water vapor dynamics in the simulated data

AIRS **q3=bt1231-bt1227** **simulated**





bt1231-bt1227 <0 means very dry air above a cloud, such that the stratosperic absorption in bt1227 dominates.
The AIRS data include many cases, the simulated data none

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The AIRS data are created with footprint which vary in size from 12.5 km at nadir to 25 km at the end of the scan line. The full scan line average is 18 km.

The ECMWF 0.25 degree grid corresponds to a 28 km uniform area.

Part of the missing clouds in the ECMWF GCM may be due to this sampling mismatch. This is not the case for low stratus and DCC which form large clusters.

The relatively accurate agreement of AIRS clear and ECMWF clear is due to the assimilation by ECMWF of clear data from AIRS, IASI, several AVHRR and HIRS, several GOES and Meteosat infared radiometers.

Evaluation for +/-30 degree Land/Ocean/Day/Night for all of 20081208

d1231=sst1231-stemp

Deep Convective Cloud (DCC) Fraction.

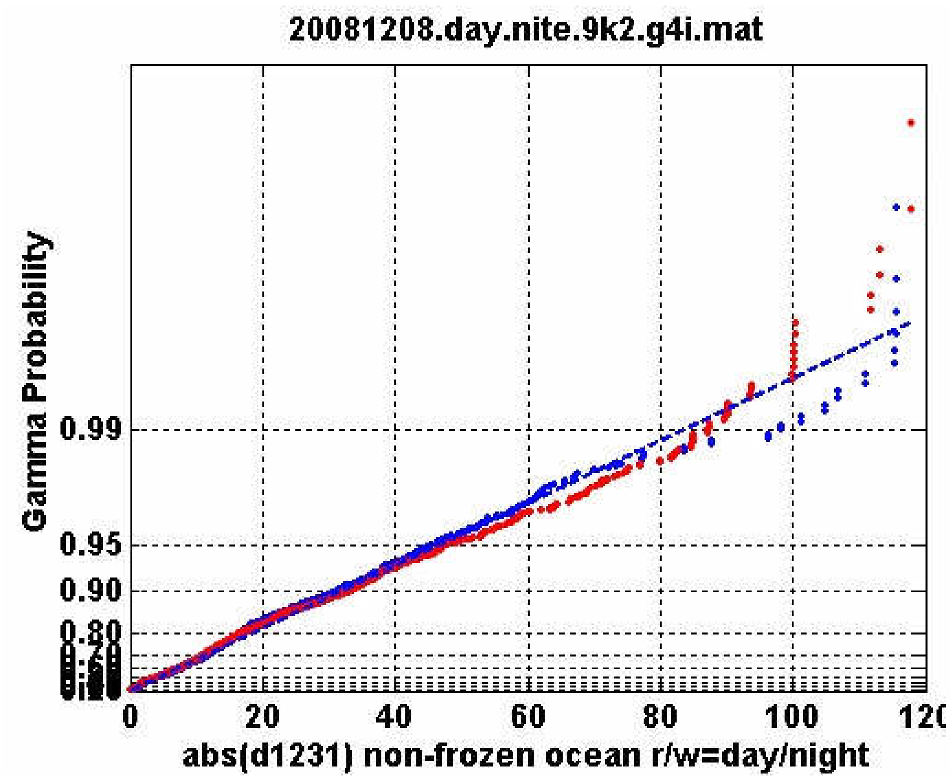
Forecast clear, defined as abs(d1231)<2 K, fraction

Low stratus fraction

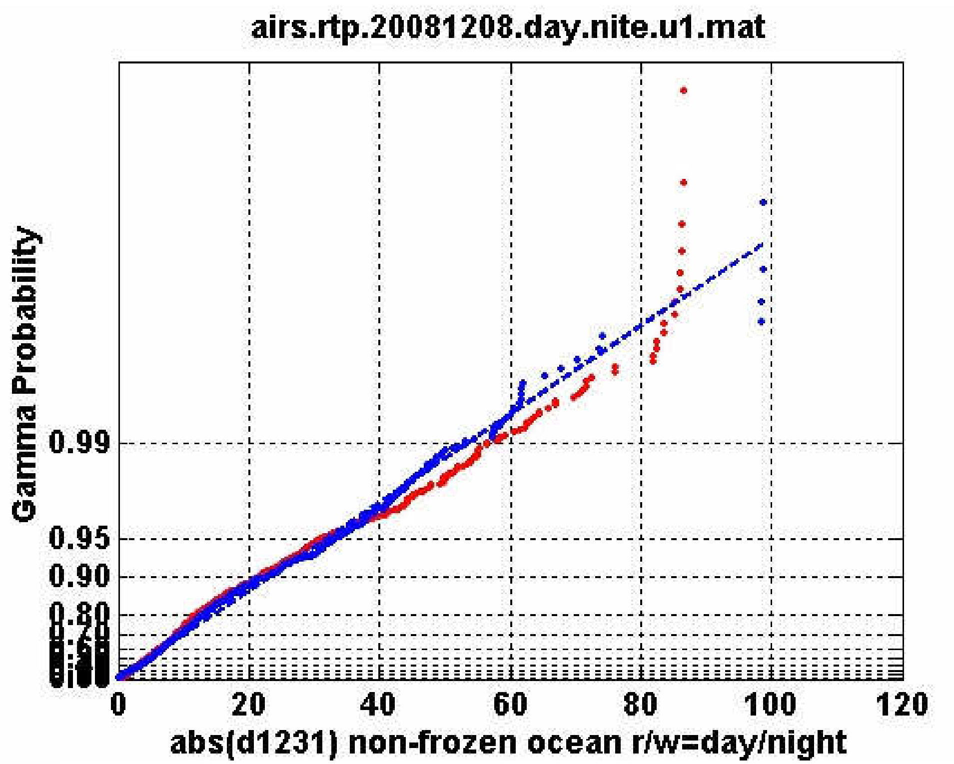
Cloud forcing d1231=sst1231-stemp

AIRS observed and ECMWF are both Gamma distributed

AIRS observed



ECMWF



Day ocean mean=11.1 std=17.5 mean=7.0
std=12.6
Night ocean 25.4 30.1
8.3 11.5

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The statistics of cloud forcing was evaluated using random nadir tropical ocean spectra

	AIRS Observed mean ± stdev	ECMWF Calculated mean ± stdev
Day ocean	-11.1 ± 17.5	-7.0 ± 12.6
Night ocean	-25.4 ± 30.1	-8.3 ± 11.5

Sampling differences and cloud modeling uncertainties cancel to first order in the day/night ratio.

25.4/11.1=2.3   8.3/7.0=1.2

AIRS has much more clouds at night than ECMWF.
Strong convection slows down in the GCM at night??

DCC frequency (DCC count/total number of footprints)

		AIRS Observed	ECMWF calculated
Ocean	Day Fraction	2.4%	0.48%
	Night Fraction	1.7%	0.41%
Land	Day Fraction	4.5%	1.13%
	Night Fraction	2.8%	0.30%

The algorithm used by the scattering RTA for converting very high clouds in to radiances is very reliable.

DCC form clusters. This makes the spatial sampling differences less important.

The discrepancies are real, not due to calculations.

DCC frequency (DCC count/total number of footprints)

		AIRS Observed	ECMWF calculated
Ocean	Day Fraction	2.4%	0.48%
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Land	Day Fraction	4.5%	1.13%
	Night Fraction	2.8%	0.30%

Frequency of DCC over ocean AIRS/ECMWF
Day = 2.4/0.48 = 5.0
Night = 1.7/0.41 = 4.1

Note that DCC more than a factor 4 more frequent over ocean in the AIRS data than in the ECMWF model.

DCC frequency (DCC count/total number of footprints)

		AIRS Observed	ECMWF calculated
Ocean	Day Fraction	2.4%	0.48%
	Night Fraction	1.7%	0.41%
Land	Day Fraction	4.5%	1.13%
	Night Fraction	2.8%	0.30%

Frequency of DCC over Land AIRS/ECMWF
Day = 4.5/1.13=3.5
Night = 2.8/0.3 = 9.3

Note the shut-down of DCC at night over land

Forecast Clear Fraction

Forecast clear is the fraction of the spectra where abs(obs-calc) for the 1231cm-1 surface channel is less than 2 K.

AIRS observed	simulated
Day 0.39	0.40
Night 0.27	0.28

The ECMWF GCM has statistically the right flavor for the clear fraction over the tropical oceans.
This is due to the assimilation by ECMWF of many infrared radiometer data under clear conditions.

Low Stratus (tropical ocean)

Low stratus is any footprint which passes all ocean clear thresholds including a 3x3 spatial homogeneity threshold of 1K, but is more than 3K but less than 30 K colder than the known tsurf.

Low stratus appear in large fields, i.e. spatial sampling differences between AIRS and ECMWF are not important.

AIRS Observed		simulated
Day	0.00004	0
Night	0.023	0.00003

No low stratus clouds in the ECMWF data

Conclusions

The qualitative agreement between the AIRS observed cloud and water vapor structure and the structure calculated from the ECMWF data is impressive.

The clouds are gamma distributed, but not as variable as in the AIRS data.

The clear fields in ECMWF are consistent with AIRS.

For PGE testing and relative performance evaluation this data set has great value: It has the right flavor for clouds and the truth for T(p), q(p), clouds and emissivity are precisely known for all 300,000 potential daily AIRS retrievals.

Conclusions (continued)

The quantitative agreement between AIRS observed clouds and ECMWF clouds is not as good.

The discrepancies in day/night ratios of observed and ECMWF clouds are not explained by calculation uncertainties or by FOV scaling.

The weaknesses of GCMs with strong convection and low stratus are also present in the ECMWF GCM.

Recommendation: Closure Test

The AIRS scattering RTA produces very realistic radiances even with the ECMWF cloud input.

A comparison of radiances calculated from the AIRS L2 derived T(p) q(p) and clouds with the observed radiances should produce even better results.

Such a closure test should become a routine part of the AIRS L2 PGE as a final quality control step.

Take-home Message

The state of the atmosphere including clouds specified by ECMWF shows difficulties with convection

Inspite of the shortcomings the conversion of this state into infrared radiances shows amazing similarities to what AIRS observes.

These ECMWF simulated AIRS (and IASI) radiances will be a major asset for the evaluation of retrieval accuracy and skill.